DEMCARE: Improving Cognitive Independence of Dementia Patients Using Machine Learning Enabled Mobile Application.

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Abstract— **Dementia is a common cognitive impairment that can be identified in society. The affected patients struggle to maintain their independence because most of the patients are looked after by caregivers. This research presents a solution for mild and moderate dementia patients to improve their cognitive independence by focusing on their thinking patterns, memory, behavior, and ability to perform everyday activities. The proposed system provides a location tracking mechanism that can define safe zones and predict locations which helps in monitoring patients' wandering behavior. The system includes a digital audio diary that keeps daily records of patients which helps to maintain the stability of memory and summarize the content. It also includes a mechanism to provide musical therapy sessions to heal the mindset of the patient by analyzing the current emotional state. Furthermore, the system can identify the patient's loved ones and interpret their relationship with the patient. All these innovations are merged in the "DEMCARE" mobile application to provide a smart solution to improve the quality of life and the independence of Dementia patients.**

Keywords—Dementia, cognitive, independence, wandering, behavior, mild, moderate

I. INTRODUCTION

Dementia patients are individuals who have a decline in their cognitive and memory abilities that interferes with their daily life and activities. It is a progressive condition that affects thinking, memory, behavior, and the ability to perform everyday activities. The number of elderly persons and life expectancy are both rising as a result of developments in medicine and technology.

It is anticipated that every 20 years, the number of people living with Alzheimer's disease will nearly double [1]. The cost of caring for a patient with dementia is high. Seven out of ten patients with the condition reside at home, where their families cover 75% of the expenses. In addition to that, the family also takes on the role of primary caregiver, which is frequently an emotionally challenging job. Family caregivers made up around one-third of those who showed symptoms of depression. Initially, it can be quite difficult for distant caregivers to continuously monitor patients as not everyone is living closer [2]. Even though it has been demonstrated that engaging in activities improves the quality of life for those who have dementia, some activities may become impossible due to the disease's symptoms. However, finding accessible activities and devices to improve the quality of life of these patients can be difficult for family members and caregivers.

Improving the quality of life of dementia patients is a challenging research problem that requires a multidisciplinary approach. One of the biggest challenges in addressing this problem is developing a system that can effectively retrieve and present memories in a way that is meaningful and relevant to the individual as all the recent memories and familiar faces wipe out from their memory. Since each person with dementia has unique requirements and preferences, it is crucial to create a memory retrieval

system that is tailored to fit those needs and preferences to improve the quality of life for those individuals.

To address these issues, we propose a solution to aid dementia individuals with better accessibility options by being able to use the application by themselves. It consists of the following four modules,

- Location tracker and predicter
- Digital audio diary
- Emotion based music player
- Face recognition system

Successfully integrating the components mentioned earlier and creating a suitable mobile-based interface with several accessibility options will enable individuals with dementia to live more comfortably day-to-day and allow them to coexist in society without feeling excluded.

II. Literature Review

A. Location tracker and predictor.

Dementia affects the cells in the brain that control memory, leading to memory impairment. People with dementia are often compelled to walk about. They don't have a place to go, or sometimes they go somewhere without knowing where they are heading to. But with memory impairment, they just feel the need to walk and move aimlessly. This is defined as "wandering" [3]. Stress, fear, overstimulation and frustration cause wandering emotionally while poor dimension perception, visual-spatial problems, poor eyesight and mobility can be physical causes. At night, boredom, perceived obligations, physical discomfort and temperature being too hot or cold can cause the same behavior [4].

In this study, we have looked at the wandering problem and its effects on dementia patients as well as their caregivers. Previous research indicates that dementia wandering is more lethal than people generally think. According to Alzheimer's Association, 60% of people with dementia are wandering during the cause of the disease [5]. There is no clear reason for this behavior; thus, wandering is unpredictable [6]. Prior research reveals alarming statistics among Alzheimer's and dementia patients: 74% of them left their residences using various means, resulting in a 30% fatality rate due to exposure, drowning, or vehicular accidents. Of those located alive, 72% were found within a day, but only 51% survived if found within two days. For those missing three to five days, survival dropped to 20%, with a distressing one in fourteen individuals not surviving [5]. In urban settings, a higher chance of survival or discovery exists, likely due to increased likelihood of assistance from bystanders. Caregivers and guardians facing these challenges are in dire need of a sustainable and effective solution to alleviate their burdens.

Since the beginning of the Covid-19 pandemic, remote patient monitoring, particularly through Mobile Health, has made significant strides in the healthcare sector. The integration of sensors has allowed for the identification of patient movement patterns, enabling the detection and reporting of unusual behavior. An analysis of existing research and systems revealed that only a few have effectively combined these elements to address wandering behavior in dementia patients. This approach has the potential to enhance the quality of dementia patient care by incorporating location-tracking mechanisms within mobile applications. However, some research implementations are lacking in real-world applications [2]. This analysis serves as the foundation for a system that studies patients' daily behavior, provides them with current and predicted locations, and offers caregivers the means to define safe zones with alert functionalities, particularly when patients are wandering.

B. Digital audio diary

Maintaining a digital audio diary by a dementia patient has an impact on the severity of the disease condition and that helps in keeping a stable mind within the patient. Research has shown that journal-keeping could reduce dementia risk. The study, "Personal Journal Keeping and Linguistic Complexity Predict Late-Life Dementia Risk" by Jessica J. Weyerman, Cassidy Rose, and Maria C. Norton revealed that, in a larger group, having ever been a journal writer strongly predicted a 53% lower risk of dementia due to all causes [7]. This study was conducted by engaging with dementia patients and their family members via telephone calls and home visits. Some researchers mentioned a diary interview technique that has been used to investigate the daily patterns of dementia patients. In the method followed by Ruth Bartlett in the above approach, a participant records his or her thoughts and feelings under the guidance of a researcher [8]. This method was further modified to examine the lives of people with dementia. When people are asked to keep a regular journal of their experiences, rich data about individual motivations, emotions, and beliefs are collected in an unobtrusive manner over time. Researchers have used these diaries, including people with disabilities, older people and the caregivers of people with dementia for their research purposes and showed the impact of it. Using digital technologies to gather audio diaries has opened up novel opportunities for utilizing this research method with elderly individuals. This approach proves particularly advantageous when considering individuals with impairments or disabilities [8]. Nearly all of the diarists and their partners stated in "AN INDEPENDENT EVALUATION OF 'DEMENTIA DIARIES' " that the project gave them a role and a purpose. Making diary entries provided them with something worthwhile to concentrate on and strive towards. Diarists felt valuable and valued when they knew that their entries were being read and were benefiting others [9]. The project utilizes 3D-printed mobile handsets to empower individuals with dementia, known as Dementia Diarists, to record diverse experiences of living with the condition. These audio recordings are made available on the Dementia Diaries website, aiming to amplify the voices of people with dementia through media exposure.

C. Emotion-based music player

There are several ways to extract face and audio elements from an audio signal, but very few of the systems created can generate an emotion-based music playlist based on human emotions. This component's main goal is to improve the previous system's weaknesses by creating an

automatic emotion-based music generator that creates a personalized playlist using user-extractable facial features.

There aren't many studies on using an emotion-based music player while targeting a dementia patient audience. According to some research work, building up music platforms was the primary objective, but the patient's emotional state has not been taken into account while implementing the application [10] [11]. Some research is inadequate since they fail to target the dementia audience and instead focus on creating an emotion-based music player which is not user-friendly for a dementia audience [12] [13]. Any of these studies, except for research [10] do not consider the users' age when producing music which helps in producing a more personalized music playlist unique to the user.

Hafeez Kabani's research project [12] focuses on creating a music player based on human emotions. The technique captures user images via webcam or hard drive but is limited to Windows programs and has specifically mentioned the poor camera quality and lighting conditions of the application. The study uses real-time EEG to recognize emotions in music therapy using hardware like the PET 2 and Emotive wireless headset. This technology enhances human-computer interfaces, but adding additional hardware, such as sensors or EEG, may increase the design's cost.

Stuart Cunningham developed Memory Tracks, an android application for dementia patients, [10] which uses music related to daily duties. The program supports routines, care, agitation management, and memory triggering. The music is selected based on demographic information, such as birth year and childhood location, rather than considering the patient's emotional state. Alive Inside [11] is a customized music-streaming app for dementia patients, offering personalized listening lists based on users' unique lives. However, as mentioned previously the app's biggest flaw is not considering patients' emotional condition when creating their profiles.

D. Face recognition system

Short-term memory impairment stands out as a prominent challenge faced by individuals with dementia, hindering their ability to recognize and identify their family members, friends, and other loved ones, which directly affects their independence, making it challenging for them to recognize familiar faces, including their own and those of their friends and relatives [14] [15]. This inability to connect with familiar faces often leads to feelings of frustration, anxiety, and emotional distress, not only for individuals with dementia but also for their family members. Consequently, the mental well-being and quality of life of both parties are significantly affected.

When studying the literature points, various tools have been built to recognize faces, and several assistive tools have also been implemented for normal people. Most of the existing solutions are implemented for a limited audience and lack functions. Non-pharmacological management of dementia puts a burden on those who are taking care of a patient [16].

To address this issue, the development of a face recognition mechanism for detecting and identifying familiar faces of dementia patients has emerged as a potential solution.

Most existing facial recognition software is designed for use by caretakers, giving them aid in keeping a close eye on their dementia patients. The uniqueness of our solution and others is that it was developed with the input of people living with dementia, considering their preferences, skills, and limitations.

By creating a real-time face recognition system, researchers aim to enhance the quality of life and independence of individuals with dementia. Despite the growing body of literature on dementia care, studies focusing specifically on real-time face recognition mechanisms for detecting familiar faces among dementia patients remain scarce. Thus, there is a need for further research in this area to explore the effectiveness and feasibility of such mechanisms in improving the lives of individuals with dementia.

Furthermore, our solution goes beyond just face recognition and adds value by incorporating additional features that are beneficial to dementia patients. For example, instead of providing a brief introduction of the person (name and the relationship between the patient), it may include prompts for memory slides regarding the captured person after detecting the person's face. These features are specifically tailored to address the needs of dementia patients, make them more interactive, and promote their well-being, and independence.

III. METHODOLOGY

A. Location tracker and predictor

In the context of this research project, the primary objective is the development of a comprehensive system that harnesses the capabilities of machine learning-enabled mobile applications to enhance the cognitive independence of dementia patients. A specific emphasis is placed on comprehending and addressing the wandering behavior exhibited by these individuals. This initiative seeks to provide caregivers and healthcare professionals with an innovative solution that is deeply rooted in insights obtained through dedicated research. The overarching aim is to empower dementia patients and elevate their quality of life.

A central element of this system is the utilization of the VT03D portable Global Positioning System (GPS) Tracker, a tracking device that offers real-time location monitoring via a mobile application. This innovative technology not only alleviates the burden on caregivers but also enables them to establish personalized safe zones for patients, granting a sense of control and customization in dementia care. The device is equipped with Subscriber Identity Module (SIM) cards and International Mobile Equipment Identity (IMEI) numbers to ensure privacy and security. It incorporates microcontrollers, sensors, actuators, enclosures, displays, and batteries, facilitating reliable and efficient functionality over extended periods with patients.

For precise and dependable tracking of patient positions, the integration of the Google Maps Application Programming Interface (API) is employed, renowned for its reliability and robust features. Geofencing technology is harnessed to create virtual barriers that correspond to real-world geographical locations, empowering caregivers to define safe zones. Radio Frequency Identification (RFID) technology plays a pivotal role in determining real-world locations and initiating messages to the system's backend.

The system is designed to excel in continuous, real-time monitoring of patient locations and movements, providing caregivers with essential flexibility and peace of mind. It ensures prompt notifications to authorized caregivers when patients breach predetermined boundaries, thereby enhancing overall patient safety. Additionally, the system gathers and retains historical data concerning patient movements, harnessing the power of machine learning algorithms, including Random Forest, to predict future patient movements. This predictive capability offers valuable insights into patient behavior and location, facilitating timely and well-informed decision-making for caregivers.

The healthcare industry is grappling with the unpredictable wandering behavior of dementia patients, which poses risks to both patients and those around them. To address this issue, a predictive Machine Learning (ML) system incorporates various algorithms, such as K-Nearest Neighbor (KNN), Random Forest, and Decision Trees, to enhance prediction accuracy. This system has been seamlessly integrated into a mobile application, enabling caregivers and guardians to access location predictions even when tracking devices are offline or malfunctioning. Caregivers can specify a date and time to determine the patient's future location, empowering them to make informed decisions about patient care and safety.

These multifaceted features significantly improve the quality of life for dementia patients and their caregivers. By prioritizing security, care, and support, the system addresses the critical issue of wandering behavior in dementia patients, which is associated with substantial risks such as road accidents, drowning, falls, and encounters with animals. Beyond patient safety, the system aims to provide caregivers with peace of mind, reduce their stress, and preserve the independence of dementia patients. This approach reflects a comprehensive and holistic strategy designed to benefit both patients and those responsible for their care.

B. Digital audio diary

This component of the project is an audio diary that can convert speech into text and generate summarizations of the text. The main reason behind adding this component to this mobile application is that diary keeping has shown a major impact in stabilizing the condition of a dementia patient. As the language literacy of a dementia patient is lower compared to a normal human being, writing or typing a diary is more difficult. Therefore, this speech-to-text-based audio diary is implemented. Furthermore, there's the ability to summarize the text provided by the patient and those summarizations are accessible to their caregivers as well. Then they can have an idea about what the patient's diary records are about. By accessing the Calander within the application, the patients can view all the diary records that they have entered and see what they have done in each and every day. These objectives were accomplished in steps; the speech-to-text conversion is done using React Native using a 3rd party package called React Native Voice and text summarization is done by building a text summarization model using machine learning and deep learning techniques.

The React native voice package allows integrating speech recognition functionalities into the app, enabling users to speak into the device's microphone and have their speech automatically converted into text. "React-native-voice" provides an event-based API that emits events during different stages of the speech recognition process. The package supports continuous listening, meaning the app can continuously listen to the user's speech until explicitly stopped. Transformers were used in building the text summarization model. A dataset was created through manual annotations and preprocessed. This involves tokenization, converting text to lowercase, removing punctuation, and any other necessary steps to clean the data and make it suitable for training. Then the textual data were transformed into a numerical BERT representation that can be used as input for the model. The model was trained on preprocessed data. By evaluating the model's performance using appropriate metrics like ROUGE for summarization tasks, the similarity between the generated summary and the reference summaries in the test set was obtained. Then the model was optimized with the hyperparameters of the model to improve its performance. Then applied post-processing techniques to make the summaries more coherent and grammatically correct. Then the model was deployed and used in integrating with the application.

C. Emotion-based music player

Dementia frequently accompanies emotional and behavioral issues and can lower a person's quality of life. People with dementia may find it challenging to express themselves verbally as the disease progresses, but even when they are unable to speak, they may still be able to hum or move to the music. It's challenging to forecast these patients' emotional states because they change so frequently. Most people with dementia seek the aid of a third party to ease their daily tasks. A third party will not be able to effectively identify the patient's emotional condition and direct them to the necessary therapy sessions in accordance with those emotions. As CNNs are specifically designed for image processing tasks and have proven to be very effective at extracting meaningful features from images here a Convolutional Neural Network (CNN) is used to extract features from the facial images and to detect the emotional state of the patient. The architecture of the CNN used in the code is designed to extract features from facial expression images and classify them into one of four emotion categories (Angry, Happy, Sad, Neutral). The CNN architecture includes convolutional layers, max-pooling layers, batch normalization layers, and fully connected (dense) layers. The CNN architecture, through these layers, learns to automatically extract relevant and discriminative features from the face images. These features are then used to make

predictions about the emotions represented in the images. According to the respected emotion detected using CNN and the registered age of the patient, they will be directed to a piece of suitable music to elevate the mood of the patient.

Here to train the model the Fer-2013 dataset for facial expression recognition is used. The fer-2013 dataset is a popular dataset used for emotion classification tasks, particularly in the context of facial expression recognition. The fer-2013 dataset includes images of faces in grayscale displaying one of seven emotion types: angry, disgust, fear, happy, neutral sad surprise. The size of each image is 48x48 pixels. Training, PublicTest (Validation), and PrivateTest (Testing) sets are the three subsets of the dataset. The training set is used to train the CNN model, the PublicTest set is used for validation during the training process to monitor the model's performance, and the PrivateTest set is used to evaluate the final model's accuracy on unseen data. The code preprocesses the data, configures the CNN model architecture, builds the model with an optimizer and loss function, augments the data to increase generalization, and finally trains the model using the fit generator function on the training data.

D. Face recognition system

This component of research aimed to develop a face recognition mechanism for dementia patients who experienced anxiety and agitation in unfamiliar surroundings or when interacting with unfamiliar faces. The "face recognition" library, a well-known Python library for facial recognition tasks, was employed as the technology for detecting and recognizing human faces. Convolutional neural networks (CNNs) are one of the machine learning methods that the library combines to find faces in images. The face detection algorithm looks through the image and finds areas where faces are probably to be present. Once faces are detected, the library extracts facial features from the detected faces. It uses a deep neural network to generate a numerical representation, called face encoding or face embedding, for each face. This encoding captures unique characteristics and patterns of the face. To perform face recognition, the library compares the face encodings of the detected faces with the encodings of known faces stored in a database or a list. It computes the similarity between the face encodings using distance metrics such as Euclidean distance or cosine similarity. A threshold value is usually set to determine whether two face encodings are considered a match. Based on the computed similarities, the library can identify known faces by finding the closest match(es) to the detected face(s) in the list of known faces. It can also determine if a detected face is unknown if it does not closely match any known face.

The face recognition application in this research uses an AWS S3 bucket to store the images of faces that are used to train and test the face recognition model. This makes it ideal for storing the large number of images that are typically used to train and test face recognition models. AWS S3 is a highly scalable, secure, and durable object storage service that offers a simple web interface to store and retrieve objects.

By utilizing AWS S3, which automatically replicates data across several data centers and provides built-in redundancy, we were able to assure the dependability and longevity of our data. The low risk of data loss and high availability provided by this redundancy makes it the perfect option for mission-critical applications like face recognition. The Python-based face recognition module was also simply integrated with AWS S3, enabling us to quickly upload, download, and manage photographs within the S3 bucket straight from our application. The straightforward API provided by AWS made it effortless to access the stored images, enabling real-time face recognition with minimal latency. In terms of security, AWS S3 provided us with various options to protect our data, such as server-side encryption and access control policies. This ensured that our sensitive image data remained confidential and was accessible only by authorized users and services.

IV. RESULT AND DISCUSSION

The study was mainly focused on providing cognitive independence to mild to moderate dementia patients and easing the workload of caregivers. The implemented components of the system are much more compatible with the selected audience. Therefore, the testing process of the application was successful and both developers and the target audience were satisfied with the final outcomes. Since the targeted audience was not young, the simplicity behind the implementation of the application was helpful in handling the application. There is the expected result in the predicted location and the live location in most of the instances of usage.

Patient locations can be promptly and accurately captured using a portable location tracker. The capacity to establish safe zones plays a crucial role in analyzing patient wandering behavior. Subsequent to comprehensive training on the accumulated data, the Decision Tree algorithm yielded the highest accuracy, an impressive 94.16%. Consequently, this aligns with anticipated results in predicted and real-time locations in most usage scenarios. Additionally, this predictive capability proved unexpectedly valuable in specific situations, including instances where the device malfunctioned or when the patient did not have the device at hand.

According to the results of using the audio diary, it has proven again that the stability of the memory can be retained at a certain condition. It was also said by the caregivers and the family members of the patients, that the patients enjoyed diary keeping as well. This is an extra benefit obtained and contentment is priceless.

The music player based on the current emotional state of the patient is highlighted as a therapy session in the routine of the patient and most of the times patients tend to listen more than once. Furthermore, the used CNN model generates the following as the results which highlights the emotion as “happy” with the accuracy of 85%.

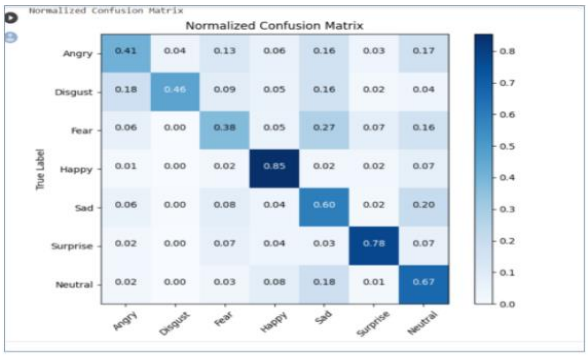

Figure 1: Confusion Matrix for Emotions

Identifying the familiar people around the patient is important in recognizing the loved ones. Patients were happy to remember the good times with them. As a combination of the mentioned features the application satisfies the objectives of the research and has immensely helpful to improve the quality of lives of the target audiences. Further, the used model library has an accuracy of 99.38% on the labeled faces.

V. CONCLUSION

In-depth analysis of Demcare mobile application research work led to an intelligent solution that improves the quality of life of dementia patients and helps caregivers manage their work effectively. This application was specifically designed for mild to moderate dementia patients who frequently struggle with managing day-to-day life activities. After identifying basic needs within the related medical sector, the app covers them with simplicity for both patients and caregivers. Since currently, available apps do not provide an overall solution to manage dementia patients, the implemented solution will be a turning point and let them live their normal life within society.

By thoroughly examining a variety of factors, this study makes a significant contribution to improving the cognitive independence of dementia patients. Although the system is built with simplicity, sophisticated technologies have been used to meet the audience's needs. The current work is an accurate, productive, efficient, and timely solution. The app is yet limited to the English language and future research could improve its accuracy for other languages. Additionally, future research could explore more regarding the timed needs and develop more features based on them. These potential research directions could enhance the usefulness of the proposed application for both patients and medical institutions.

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